



# Exploring the Quartz Compositor

**Session 503**





# Exploring the Quartz Compositor

**Peter Graffagnino**  
**Director, Graphics and Imaging Engineering**

# Agenda

- Introduction
- Quartz Compositor
  - Architecture
  - Software implementation
- Quartz Extreme
  - OpenGL implementation
  - Leveraging it in your app



Aqua

Frameworks

Quartz

OpenGL

QuickTime

Darwin



**Quartz**

**OpenGL**

**QuickTime**

**Quartz Compositor**



# Window System as a Digital Image Compositor

# COMPUTER GRAPHICS

Volume 18 • Number 3 • July 1984  
A quarterly report of ACM SIGGRAPH

SIGGRAPH '84 Conference Proceedings  
July 23-27, 1984, Minneapolis, Minnesota  
Edited by Hank Christiansen



## Compositing Digital Images

Thomas Porter  
Tom Duff†

Computer Graphics Project  
Lucasfilm Ltd.

### ABSTRACT

*Most computer graphics pictures have been computed all at once, so that the rendering program takes care of all computations relating to the overlap of objects. There are several applications, however, where elements must be rendered separately, relying on compositing techniques for the anti-aliased accumulation of the full image. This paper presents the case for four-channel pictures, demonstrating that a matte component can be computed similarly to the color channels. The paper discusses guidelines for the generation of elements and the arithmetic for their arbitrary compositing.*

CR Categories and Subject Descriptors: 1.3.3 [Computer Graphics]: Pictures/Image Generations — Display algorithms; 1.3.4 [Computer Graphics]: Graphics Utilities — Software support; 1.4.1 [Image Processing]: Digitization — Sampling.

General Terms: Algorithms

Additional Key Words and Phrases: compositing, matte channel, matte algebra, visible surface algorithms, graphics systems

### 1. Introduction

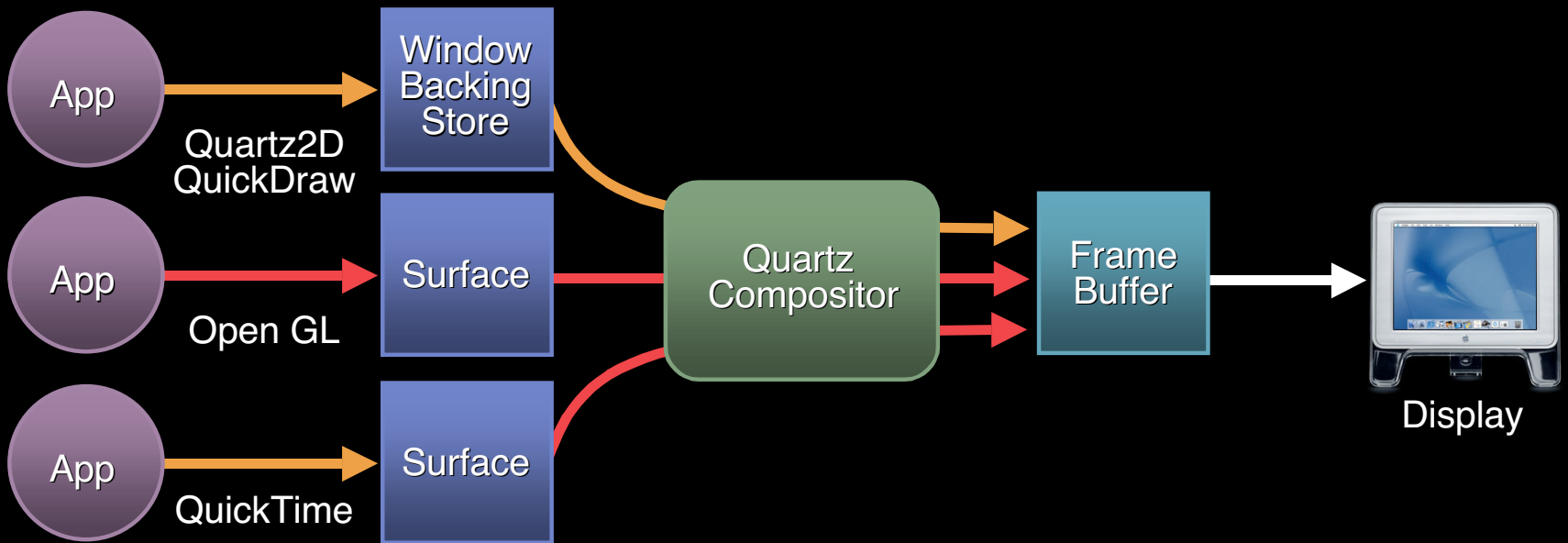
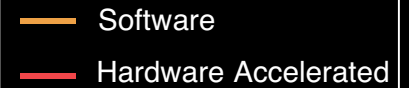
Increasingly, we find that a complex three dimensional scene cannot be fully rendered by a single program. A wealth of literature on rendering polygons and curved surfaces, handling the special cases of fractals and splines and quadrics and triangles, implementing refinement, texture mapping and bump mapping, noting speed-ups on the basis of coherence or depth complexity in the scene suggests that multiple programs are necessary.

In fact, reliance on a single program for rendering an entire scene is a poor strategy for minimizing the cost of small modeling errors. Experience has taught us to break down large bodies of source code into separate modules in order to save compilation time. An error in one module forces only the recompilation of its module and the relatively quick reloading of the entire program. Similarly, small errors in coloration or design in one object should not force the "recompilation" of an entire image.

Separating the image into elements which can be independently rendered saves enormous time. Each element has an associated matte, coverage information which designates the

# Quartz Compositor

Legend







iMac Window Ad.mov

00:00:21

Navigation View Style Options

PowerBook G4.pdf

## PowerBook G4

Whether you use a Mac, Windows, or UNIX system, your search for the world's best high-performance thin and light notebook computer is over. The new PowerBook G4 easily runs everything from Microsoft Office to Final Cut Pro to Adobe Photoshop. It also connects to just about anything, from wireless networks to digital cameras to the stunning Apple Cinema Display. Truly a study in contrasts, the PowerBook G4 gives you a gorgeous 15.2-inch mega-wide screen and up to 5 hours of battery life\* in an unrivaled 1-inch-thin titanium design that weighs as little as 5.4 pounds.

With a PowerPC G4 processor with Velocity Engine running at up to 800MHz—and 1MB of L3 cache for an extra performance boost—the PowerBook G4 is a truly powerful and portable computer. In fact, it delivers performance that surpasses Pentium 4-based notebooks by up to 33 percent in Adobe Photoshop testing.† For superior performance in graphic design work, DVD movie playback, and 3D gaming, the PowerBook G4 features the ATI Mobility Radeon 7500 graphics processor with 32MB of DDR SDRAM. Complementing this performance platform is Mac OS X—a supermodern operating system that combines the power and stability of UNIX with the elegance of Macintosh.

Such incredible power deserves equally impressive display capabilities. The PowerBook G4 features a new 15.2-inch mega-wide screen with 1280-by-854-pixel resolution, which gives you the largest workspace, best color saturation, and widest viewing angle ever in a PowerBook. Compared with 15-inch XGA screens, you get 39 percent more workspace. If you need to increase your workspace even more or deliver a presentation, the PowerBook G4 features DVI, VGA, S-video, and composite output options for connectivity to flat-panel displays, CRTs, TVs, and projectors. And for the first time ever, you can have the ultimate pure digital experience and even more workspace by connecting your PowerBook to an Apple flat-panel display.‡

When it comes to networking, the PowerBook G4 has you covered. With an AirPort Card, you're ready to connect to a wireless network at work, at home, or in a café.‡ If you're looking for a high-speed connection via Ethernet, DSL, or cable modem, just plug into the Gigabit Ethernet port. Of course, there's a built-in 56K modem as well.‡ You can also use Bluetooth wireless technology to link Bluetooth-enabled PDA's, cell phones, and other peripherals to your PowerBook G4.‡

The PowerBook G4 provides multiple ways for you to express your creativity. With the slot-loading Combo drive (DVD-ROM/CD-RW), you can burn CDs, watch DVD movies, or listen to music. CDs, FireWire, USB, and audio ports provide connectivity to devices like iPod, DV cameras, and external microphones to help you make movies, download digital photos, or even compose your own music.

The PowerBook G4. Accomplish more. Carry less.

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Page 2

Page 3

Page 4



- Next Steps**
- Combo drive (DVD-ROM/CD-RW) for optical CD burning and audio line-in and out ports, and
  - PC Card Slot
  - Optional Bluetooth technology for wireless connectivity
  - iMovie 2 or optional Final Cut Pro 3 software for digital video editing
  - iTunes 2 software for managing your digital audio collection, auto-updating iPod, and creating music CDs
  - Photo software for managing your digital photos



620	Clock	0.0%	0:01.39	1	57	86	1.59M	5.45M	3.32M	166M
617	Preview	0.0%	0:26.67	2	68	144	3.83M	20.5M	12.7M	194M
595	QuickTime	0.0%	0:24.16	6	121	202	6.29M	11.4M	11.7M	186M
532	System	4.6%	3:28.21	1	16	20	236K	612K	564K	13.9M
516	System	0.0%	0:00.03	1	12	19	352K	868K	884K	6.02M
514	login	0.0%	0:00.04	1	14	36	88K	552K	508K	13.9M
513	Terminal	1.8%	1:19.79	4	72	247	2.70M	8.50M	7.05M	171M
505	SecurityAg	0.0%	0:01.27	2	82	94	1.48M	5.59M	3.79M	166M
458	System	0.0%	0:01.95	2	133	121	1.44M	5.77M	3.16M	162M
454	Dock	0.0%	0:14.16	2	101	136	1.48M	11.7M	8.50M	166M
450	pbs	0.0%	0:01.47	2	36	33	980K	980K	1.86M	15.1M
415	DirectoryS	0.0%	0:01.41	6	72	109	1.24M	2.71M	3.78M	22.4M
401	automount	0.0%	0:00.23	2	10	36	692K	1.57M	856K	16.7M
399	CCacheServ	0.0%	0:00.03	1	17	24	148K	1.11M	820K	14.6M

iTunes





# Quartz Composer: Architecture

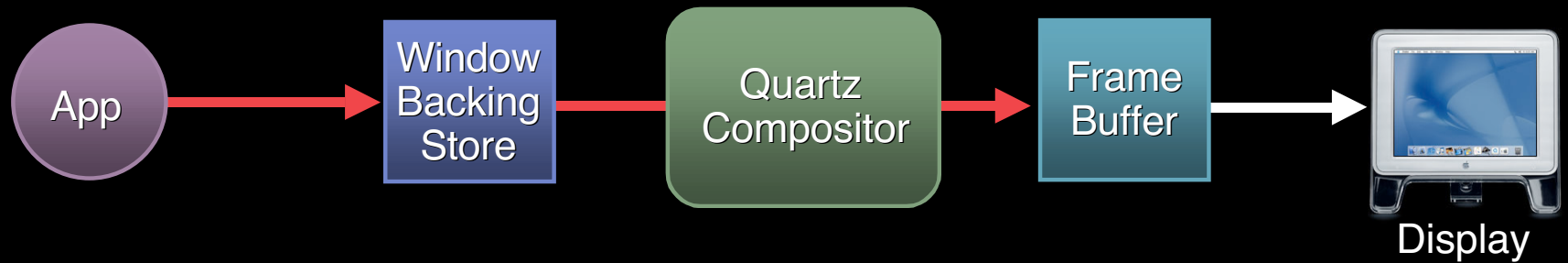
**Ralph Brunner**  
**Mineralogist**

# Composers and Other Musicians

- Quartz compositor produces on-screen presentation by combining window content from different applications
- Enables effects like drop-shadows, scaling of content, translucency, and window transformations



# Man Behind the Curtain . . .



# Don't Forget to Flush

- For the most part, Cocoa and Carbon take care of this for you
- Use `CGContextFlush()` to present result on-screen
- Flushing is synced to the display refresh
- Flushing is asynchronous for application

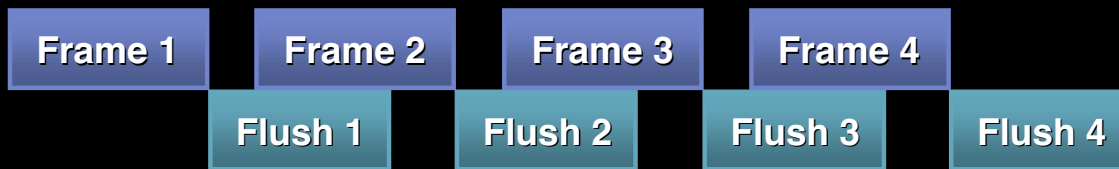


# More Fun for the Same Price

## Synchronous Flushing



## Asynchronous Flushing



Time 





# Demo

**Asynchronous Flushing**

# Under Pressure?

- Window buffers can be compressed
- 'Idle' windows get compressed after a few seconds
- Damage repair is possible directly from compressed windows
- Transparent to applications: LockPortBits() decompresses window if needed



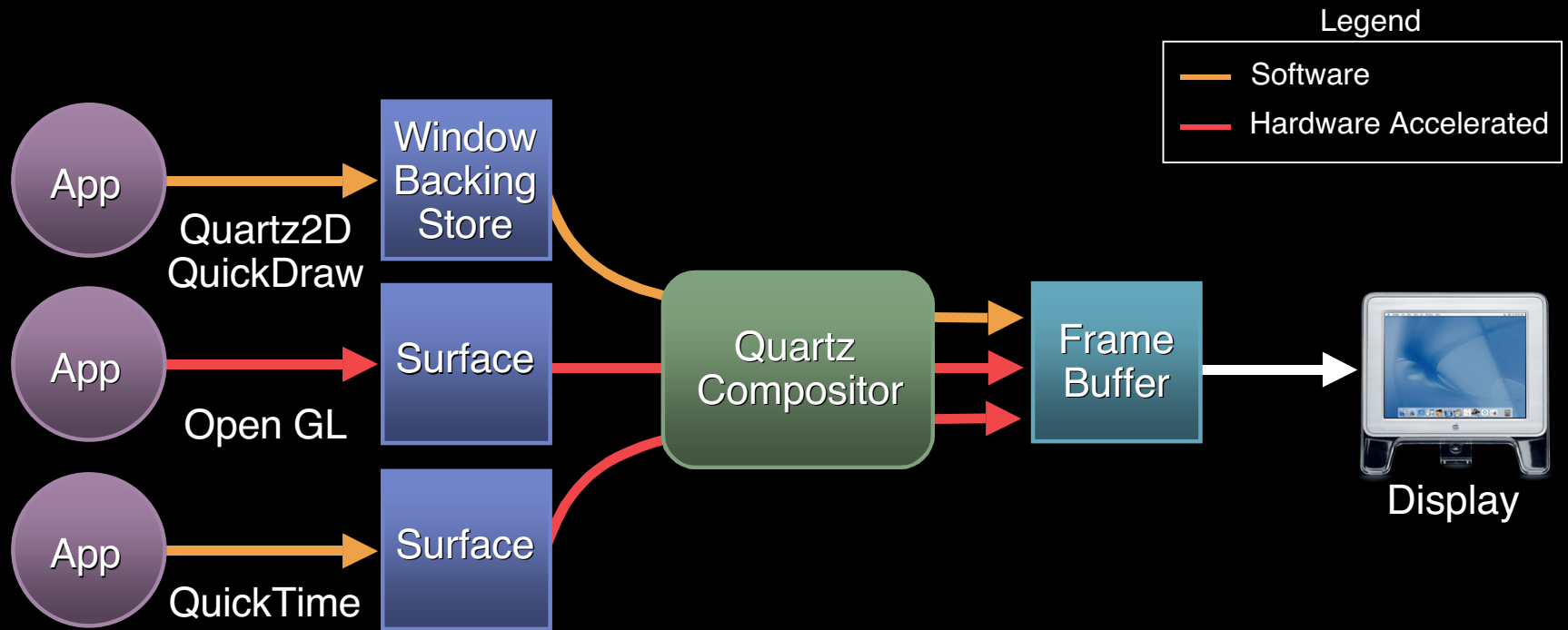


# Surfacing Issues


- A surface is an additional buffer for part of a window
- Any number of surfaces can be attached to a window
- Mainly for OpenGL and Video content
- Seamless mixing of 3D, 2D, and DVD



# Quartz Compositor



# Jaguar Quartz Compositor

- Blending is done with CPU
- Makes use of multiple CPUs
- 2D hardware acceleration for window moves
- Compositor uses Velocity Engine
-  2D hardware acceleration for scrolling





# Quartz Extreme



**Peter Graffagnino**

# Why Extreme?

- Model can be computationally expensive
- “You took the framebuffer away . . .” .
- We’ve built the foundation for the future
- Now we can complete the story . . . .



# Quartz Extreme

- Implementation of Quartz Compositor on OpenGL
- Removes “transparency tax” for video and 3D
- Frees up CPU
- Showcases GPU in user interface
- Allows us to deliver even more dramatic UI advances for our users



# Programmed I/O vs. DMA

- Programmed I/O Model
  - CPU pushes data and commands to device
  - Inefficient use of CPU
- DMA I/O Model
  - Device pulls data and commands from memory
  - CPU and I/O occur in parallel
- CPU drawing in the framebuffer is really just programmed I/O!





# More Moore's Law

- CPU:
  - Performance doubles every 18 months
  - G4: 10 million transistors
- GPU:
  - Performance doubles every 6 months
  - “Moore’s law cubed”
  - GeForce4 Ti: 63 million transistors



# New Graphics Platform

- Next generation windowing system, today
- Not a hack, we've done it right
- Inflection point in platform graphics
- Blend of
  - ATI/NVIDIA's GPU advances
  - Apple's graphics architecture innovations
- Our advances are directly useable by you via Jaguar OpenGL





# Quartz Extreme: Implementation

**Kenneth Dyke**  
**Sr. Mad Scientist**

# Quartz Extreme

- Accelerates all compositor operations
- Does not accelerate Quartz 2D or QuickDraw
- Implemented in OpenGL



# Why OpenGL?

- 2D acceleration is “done”
  - Stick a fork in it
- 3D acceleration is still advancing rapidly
  - Near gigapixel fill rates
  - Lots of video memory
  - Good support for 2D data
- OpenGL is the industry standard for 3D
  - Most GPUs are modeled after OpenGL



# OpenGL on Mac OS X Rocks!

- Advanced resource management
- Tight integration with the OS
- Heavy involvement in driver development
- Many new extensions driven by compositor needs
  - GL\_client\_storage and GL\_texture\_range



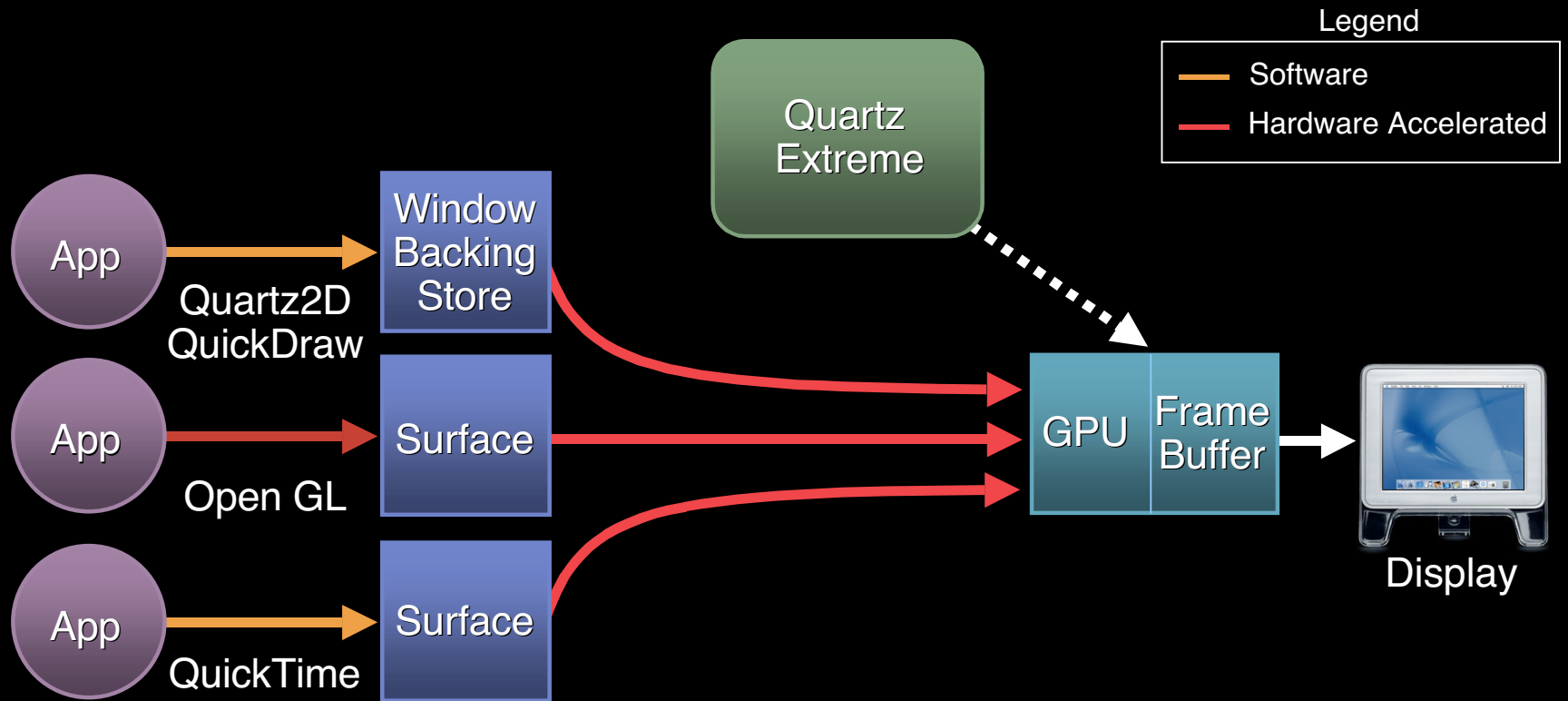
# Just Another OpenGL Application

- Quartz Extreme uses OpenGL like any other application
- The desktop is a 3D scene
- Everything is a textured polygon
- Compositing via blending and multitexture





# Quartz Extreme



# GPU Requirements

- 32MB of video memory recommended
- AGP 2X required
- Direct support for Quartz data formats via DMA
  - ARGB8888, ARGB1555, A8, 2vuy, yuvs
- Non-power of two textures
- Multi-texture
- 256MB system memory recommended



# Supported GPUs

- GeForce2MX, GeForce3, GeForce4MX and GeForce4
- Radeon AGP
- Rage 128 and earlier chipsets will not be supported
  - The functionality is not there





# Demo

**Quartz Extreme**

**Compositing Performance**

# No Transparency Tax

- Dramatically lowered CPU overhead for Aqua
- Seamless integration of different media
- Exciting new possibilities
  - Overlay windows
  - Underlay surfaces
  - Other cool stuff



# Underlay OpenGL Surfaces

- Move OpenGL surface beneath Window
- Independent buffers
- QuickDraw or Quartz 2D over 3D
- Carbon or Cocoa controls over 3D





# Demo

**Quartz Extreme**

**Underlay Surfaces**

# Changing Surface Ordering

- Surfaces may be ordered above or below window
- Cocoa

```
long order = -1;
```

```
[myGLCtx setValues:&order  
forParameter:NSOpenGLCPSurfaceOrder];
```

- Carbon

```
GLint order = -1;
```

```
aglSetInteger(myCtx, AGL_SURFACE_ORDER,  
&order);
```





# Underlay Drawing

- Must “cut hole” using clear color

```
[[NSColor clearColor] set];  
NSRectFill([self bounds]);  
CGContextClearRect()
```

- Avoid redundant clears
- Watch out for extra flushes



# Transparent OpenGL Surfaces

- Compositor can use surface alpha channel
- Surface content must be premultiplied
  - Render on clear background
  - Enable blending





# Demo

Quartz Extreme

**Transparent Surfaces**

# Enabling Surface Transparency

- Cocoa

```
long opaque = 0;  
[myGLCtx setValues:&opaque  
forParameter:NSOpenGLCPSurfaceOpacity];
```

- Carbon

```
GLint opaque = 0;  
aglSetInteger(myCtx,  
AGL_SURFACE_OPACITY, &opaque);
```



# Performance Concerns

- Transparent surfaces and underlays supported in software
  - Small surfaces should be okay
  - Bottleneck is CPU read from video memory
- Use `CGDisplayUsesOpenGLAcceleration()` if performance is critical



# Summary

- Reduced CPU usage
- Ultra fast compositing
- Seamless integration of 3D content
- Transparent windows/surfaces are better than overlays



# Roadmap

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**500 Graphics and Imaging Overview**

Room A2  
**Tue., 10:30am**

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**501 Quartz 2D and PDF**

Room A2  
**Tue., 2:00pm**

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**503 Exploring the Quartz Compositor**

Hall 2  
**Tue., 3:30pm**

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**504 OpenGL:  
Graphics Programmability**

Room A2  
**Tue., 5:00pm**



# Roadmap

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**505 OpenGL: Integrated Graphics I**

Room J  
**Wed., 9:00am**

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**506 OpenGL: Integrated Graphics II**

Room J  
**Wed., 10:30am**

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**109 Darwin Printing**

Room J  
**Wed., 2:00pm**

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**509 ColorSync and Digital Media**

Room C  
**Wed., 5:00pm**





# Roadmap

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**510 Printing and Mac OS X**

Hall 2  
**Thurs., 10:30am**

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**513 OpenGL: Advanced 3D**

Room J  
**Thurs., 3:30pm**

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**514 OpenGL:  
Performance and Optimization**

Room J  
**Thurs., 5:00pm**

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**515 Image Capture Framework**

Room C  
**Fri., 2:00pm**



# Roadmap

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**516 Graphics and Imaging  
Performance Tuning**

Hall 2  
**Fri., 3:30pm**

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**FF018 Feedback Forum**  
Graphics and Imaging

Room J1  
**Fri., 5:00pm**



# Who to Contact

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**Travis Brown**

Graphics and Imaging Evangelist

**[Travis@apple.com](mailto:Travis@apple.com)**

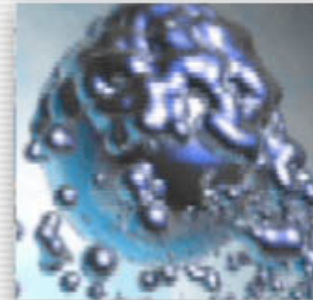
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<http://developer.apple.com/wwdc2002/urls.html>





# Q&A



**Travis Brown**  
**Graphics and Imaging Evangelist**  
**Worldwide Developer Relations**

<http://developer.apple.com/wwdc2002/urls.html>



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